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ANIMAL NUTRITION IN THE TROPICS

IN temperate regions it has been possible through well equipped centres to carry out a considerable amount of research on animal nutrition and much knowledge has been and still is being accumulated on livestock feeding problems. The nutritive value of many kinds of animal feeding stuffs has been determined and with the data obtained farmers are able to calculate accurately the rations fed to their livestock. In the tropics, on the other hand, both the data collected and the amount of scientific work which has been done on the nutritive values of animal feeding stuffs have been very limited. It is true that the digestibility figures of a number of processed products of tropical crops are available but little attention has been paid to the crops themselves, as grown in their own environment. In many cases the coarse fodders fed to livestock have been almost entirely uninvestigated. Furthermore, no comprehensive list of feeding standards has been made available. Animal feeding in the tropics thus has had to depend on "hit or miss methods" and cannot, for lack of adequate information, be strictly carried out on a scientific basis. All that the tropical farmer can do and "faute de mieux," in effect does, is to base his feeding methods on American or European standards. Thus, there is great need for extended work in this sphere of tropical agriculture.

It is generally recognised that in a scheme of livestock improvement progress can usually be achieved when concurrently an improvement in the diet of the livestock is effected. Without good feeding, races of cattle are bound to degenerate and breeding work must be impaired. The problem is complicated by the facts that it seems reasonable to assume, and most workers do thus assume, that there will be some appreciable difference in the fundamental metabolism of such different animals as cattle of the *Taurus* and *Indicus* breeds, and, in particular, in cattle of the *Taurus* breed when in such different environments as those of the tropical and temperate zones. But such differences, if they exist, can only be fully established by fundamental research of which digestibility trials are only one step. Assumptions such as seem often to be rather casually made that "humped cattle have better digestive ability" or "have greater capacity for coarse fodders" than European cattle are not only useless but also dangerous in the present state of our knowledge.

Another problem in the tropics is that of the shortage of protein rich fodders. One authority ascribes the degeneration of *Bos taurus* in the tropical regions to inferior rations lacking in protein and containing a high percentage of fibrous and indigestible material. Another authority calls for the growth of more leguminous crops and there is, in the tropics, a definite need for a fodder which would serve the same purpose as that which lucerne or clovers serve in the temperate regions. The shortage of protein rich foods is illustrated by the fact that the larger tropical dairies, where a successful breeding programme has been carried out and a high standard of milk production has been reached, have been relying to quite an inordinate extent on expensive imported concentrates to supply the deficiencies of local feeds. This reliance on imported feeds becomes impossible in time of war, and its economy in times of peace is not assured.

The first step in the scientific study of the problem of improved nutrition is to carry out digestibility trials. We are publishing in this issue the results of some of these trials conducted at intervals over a period of ten years at this College. It will be seen that our attention here has been directed chiefly to the study of the more promising fodders including the tall, perennial grasses which yield a heavy weight per acre of fodder per annum. Analytical data are now available on some of these grasses and also on some leguminous crops which may, by themselves, or used in mixtures, prove suitable as cattle fodders. At the same time the study of the optimum age of cutting of the more common perennial fodder grasses with special reference to protein content has been commenced.

From the results obtained it appears that the digestibility figures do not differ greatly from those secured in other tropical countries with material of similar age, grown under similar conditions and rainfall. The trials have established, however, that nearly every animal used in the investigations consumed markedly less dry matter than the standard quantity required for the maintenance of cattle in a temperate climate. It should not yet be concluded, however, that the dry matter requirements of cattle in the wet tropics are lower than they are in temperate regions. Experiments on the feeding of wilted fodders revealed that the digestibility of the protein and starch in the fodder was but slightly reduced, although that of the crude fibre was more substantially reduced. The results obtained in these experiments were considered sufficiently encouraging to warrant further and more elaborate trials. Investigations into leguminous crops such as woolly pyrol and velvet bean indicate that both are too rich when fed alone to stock, this applying more especially to woolly pyrol; and further that they are liable to cause scouring, especially in cattle of *Taurus* origin. It is likely that the chief use of these leguminous crops in future will be for the purpose of balancing protein deficient rations of fodder grasses.

NOTE ON TWINNING CACAO SEEDLINGS *

BY

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Accounts of twinning *Hevea* seedlings are so numerous that no attempt will be made here to give references, but no description has been found in the literature available of any attempt to twin cacao seedlings. The method used at the Central Cocoa Research Station on the Gold Coast is so simple and successful that it can be used extensively either for doubling a limited quantity of valuable material after introduction, or for experiments where clonal pairs are desirable, as in work on virus strains.

Beans are sown in sand in boxes, which are moved into direct sunlight immediately after germination. This reduces the length of the hypocotyl to a minimum. As soon as the cotyledons have separated completely, the plumule is cut off to stimulate the bud in the axil of each cotyledon. A two-stemmed seedling results. Before the first foliage leaves appear, the seedling is lifted, the sand washed off the roots, and the hypocotyl and tap-root bisected longitudinally with a razor blade so that the resulting twins each have an uncut stem, but only half the hypocotyl and tap-root and one cotyledon. The seedlings are then planted in baskets and kept well shaded. Growth usually continues without any apparent check and the few deaths that have occurred were due to the cotyledon having been broken off or to the cut being far from medium; in the latter case there is no loss of original material because only the thinner twin dies. Using this technique, mortality has amounted to 3 per cent. of the twins.

* This note is published by kind permission of Mr. H. B. Waters, Director of Agriculture, Gold Coast.

MANGANESE DEFICIENCY IN CITRUS

According to an article published in the *Proc. Amer. Soc. Hort. Sci., 39 : 51–8*, manganese deficiency was found to be widespread in California. Symptoms, which differ from those of zinc deficiency, are generally mild and occur both on highly productive and decadent trees. Severe deficiency symptoms were in some areas associated with early decline of lemon trees. Sprays, including manganese sulphate and soda ash 10–5–100 and 4–2–100 respectively, proved successful in some cases. In others, when followed by fumigation, they resulted in burning of young orange the lemon leaves.

DIGESTIBILITY TRIALS ON GREEN FODDERS

Experiments conducted at the Imperial College of Tropical Agriculture, 1931-41

BY

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In many tropical countries the pasturage is not good enough, or there is not enough of it throughout the year, to provide forage for all the cattle a man wishes to keep. It may be thought that the rainfall, humidity, and uniform temperature found in the wet tropics throughout the year would favour pasture and the formation of pastures, yet this is not usually so. Much more attention such as controlled grazing, drainage, weeding and mowing is necessary to maintain a pasture in good condition than in temperate climates, and if this attention is not consistently and continually given, the valuable grasses of the pasture are liable to be replaced quickly by coarse valueless ones, or even by rough scrub. In the wet tropics, therefore, wherever anything in the way of a commercial cattle industry (which generally means dairy farming) has been established, the tendency is toward the "soiling" of crops, grown on arable land, in a partial or even complete substitution for grazing. It is true that the grazing of "fodder crops" and "fodder grasses" is practised, but there is a strong prevailing method of cutting these fodders and carrying them to the stock. This is termed "green soiling". During the rainy season these fodders supplement the grazing, and in the dry season provide a very large proportion of the coarse fodder ration.

In the wet tropics this bulky fodder portion of the ration assumes particular importance, for as a rule the climatic conditions are favourable to its development and far less favourable to the cheap production of "concentrates" (with the exception of coconut meal and palm-kernel cake). Therefore concentrated stock-feeds are usually imported because it is cheaper to do that than to produce them. With fodder cheaply grown, and concentrates relatively dearly bought, it obviously should be the objective of the cattle-keeper in such a situation to make the best possible use of his home-grown fodders and to use the minimum possible amount of imported "concentrates."

For various technical reasons, the ideal fodder would be one which, once planted, would stand for some three or four years in spite of repeated cuttings at intervals of a few weeks. The same factors which adversely affect the cheap production of concentrates in the wet tropics also adversely affect cheap production of those fodder crops which occupy the land for only a few months at a time. Moreover, hay-making is not really practical in the wet tropics, so that again the most important fodders are those which can be cut as required from day to day, rather than annual crops which must be cut practically all at once when they are ready. The ideal perennial fodder undoubtedly would be a leguminous crop, or a mixture of a legume and grass. However, a satisfactory leguminous fodder for the wet tropics has yet to be found, with the result that the most promising fodders we are left with are the more or less perennial grasses, especially the tall-growing grasses which yield a heavy weight per acre per annum.

During the last 10 years a good deal of investigational work has been carried out on the field aspects of fodder crops at this College (1). Naturally this work has dealt chiefly with grasses of the type just described, although some attention has been given to other fodders which might have economic or practical advantages under local conditions. Concurrently with these field studies, digestibility trials of the fodders, using cattle, were carried out by a number of post-graduate students: J. P. Maule in 1930, R. E. T. Hobbs in 1931, E. S. Capstick in 1939, C. A. Walker in 1940, B. J. Silk and B. C. Wills in 1941. And this year two more students are working on the same subject. The fodders studied include the following:—

	Digestibility trials
Elephant Grass (*Pennisetum purpureum*)	3
Guatemala Grass (*Tripsacum laxum*)	4
Para Grass (*Brachiaria mutica*)	2
Savannah Grass (*Axonopus compressus*)	1
Bamboo Grass (*Paspalum fasciculatum*)	1
Guinea Grass (*Panicum maximum*)	1
Sugar Cane (*Saccharum officinarum*)	2
Cane Tops	2
Sweet Potato Vines (*Ipomea batatas*)	1
Velvet Bean Vines (*Mucuna aterrimum*)	2
Woolly Pyrol (green) (*Phaseolus mungo*)	1
A mixture of Velvet Bean and Guatemala Grass	1
A mixture of Velvet Bean and Elephant Grass	1
A mixture of Woolly Pyrol and Guatemala Grass	1
A mixture of Woolly Pyrol and Elephant Grass	1

(1) Summarised in *Tropical Agriculture*, **16**, 55-7 and **18**, 226-8.

In each case these digestibility trials were carried out with groups of four cattle. This number, dictated by our limited resources, is recognised to be inadequate, a well-matched group of at least eight cattle being desirable. The animals used were pure-bred Zebu, a few pure-bred European cattle, and half and three-quarter European-Zebu stock. No difference in their ability to digest the constituents of the food which could be attributed to breed could be detected. The variation among the individuals within the same class was greater than the observable difference between classes. Therefore in preparing the Table of Results, it was not considered necessary to indicate the breeding of the animals in each trial. There was some indication that animals of "European" origin have greater capacity for fodder in that they daily consume more in relation to their weight than stock of "Zebu" origin. The adverse factor of the limited number and mixed breeding of the animals is partly compensated by the fact that more than one trial was carried out with each of the more important fodders. The usual system was followed, namely, a period of preparatory feeding with the experimental fodder lasting for five to eight days, followed by an actual trial period usually of eight days. Standard methods of sampling and analysing were also followed. Apart from the matter of the small number of cattle used in each trial, the results are believed to be of reasonable accuracy. The results of all these trials are presented in the Table. It might be added that the series of trials is still in progress.

In general, the digestibility figures found in these trials, and given in the Table, do not differ greatly from the results obtained in other countries with material of similar age, grown under similar conditions and rainfall, and there are only one or two points which call for comment.

What invariably emerges from these trials is that although the cattle were daily fed more fodder than they would eat, they consumed only some 1.6 lbs. of dry matter per 100 lbs. liveweight, as against the 2.2 lbs. of dry matter per day per 100 lbs. liveweight standard for the maintenance of cattle in a temperate climate. A total of 96 individual trials may seem insufficient in number to justify a suggestion that a different standard requirement of dry matter is applicable in the tropics. However, not only did each of these groups of four cattle consume less on the average than the accepted amount of dry matter, but practically every individual animal consumed markedly less than the standard quantity of dry matter (in spite of the considerable variations between individuals in appetite and digestibility already mentioned). This fact therefore seems at least to merit consideration.

The most obvious explanation for the foregoing observation would be that the fodders used contained too much moisture, and therefore the animals were simply not able to eat enough bulk to obtain all the dry matter they required. This contention, however, seems to be refuted, in some degree when the trials are grouped according to the dry matter in the fodders, viz. :

A. Dry matter in fodder under 20 per cent.—36 unit trial periods. Average quantity of dry matter consumed daily was 1.58 lbs. per 100 lbs. liveweight.

B. Dry matter in fodder over 20 per cent. and under 25 per cent.—36 unit trial periods. Average quantity of dry matter consumed daily was 1.51 lbs. per 100 lbs. liveweight.

C. Dry matter in fodder over 25 per cent.—24 unit trial periods. Average quantity of dry matter consumed daily was 1.62 lbs. per 100 lbs. liveweight.

Group C admittedly comprises cane tops, mature cane, etc., and generally were unpalatable, whereas in the other groups the fodders were known to be palatable.

In the majority of these experiments the cattle were weighed daily and most of them were found to maintain their weight, or even increase it.

The quantity of starch equivalent and protein equivalent contained in the dry matter actually consumed was, in fact, slightly in excess of the accepted standard requirements for the maintenance of cattle in temperate climates. And we know that in practice many oxen not only maintain their weights but actually work on a diet continuously deficient in dry matter according to accepted temperate zone standards. On these trials and experience, however, one could not conclude that the dry matter requirements of cattle in the wet tropics are lower than they are in temperate climates. Even were it so, there is much to be said for devising means whereby cattle could consume more dry matter conveyed in the bulky fodder part of the ration.

As has been pointed out already, it would be economical to do so. For by such means, it would be possible to provide a part of the ration for production as well as maintenance in the form of cheap fodder instead of expensive concentrates. And since it is generally believed (and the belief supported by some experimental evidence) that the digestibility of the nutritive constituents of the ration is somewhat decreased if it contains an inadequate amount of dry matter, then the means of providing a richer drier fodder is all the more worthy of study.

This drying may consist of wilting the green material, a process called "quailing" in the West Indies, of hay-making, or of rapid drying in artificial driers. But hay-making in the wet tropics is not a practical proposition, for the hay, if made, too readily becomes musty. Artificial drying may have a place, but at present its economic use is limited because the young grass that could be grown is not rich enough to justify drying. The most practical method of partial drying is air-wilting. This wilting of green fodder prior to feeding is not a new practice. An old method was spreading the fodder thinly over a barn floor where it remained in reasonably good

TABLE OF RESULTS

Name of fodder.	Age of Cut.	Date of Cut.	Rain on Crop Cut.	Analyses of :—	Moisture.	Total D.M.	Ash.	C.P.	T.P.	Fibre.	E.E.	N.Free extrac	S.E.	P.E.	D.M.
		Trial I		(*a*) Fresh Material ...	79.20	20.80	3.07	1.31	1.18	7.19	0.29	9.66			
Bamboo grass	10 weeks	*Capstick*	14"	(*b*) Coefficient of Digestibility (Average)	—	52.5	23.0	49.6	47.5	61.0	80.8	51.5			
		Nov., 1940		(*c*) Digestible Analysis of (*a*)	—	10.9	0.60	0.65	0.56	4.39	0.23	4.97	9.47	0.61	20.8
		Trial I		(*a*)	80.10	19.90	2.71	1.88	1.58	6.78	0.32	8.21			
		Capstick		(*b*)	—	56.5	31.2	67.0	62.1	55.7	67.9	58.2			
Para grass	8 weeks	Dec., 1940	6.5"	(*c*)	—	11.25	0.90	1.26	0.98	3.77	0.22	4.78	9.18	1.12	19.9
		Trial II		(*a*)	75.4	24.6	2.5	1.9	1.88	7.8	0.31	12.8			
		Walker		(*b*)	—	55.2	—	66.7	57.1	55.6	67.3	57.5			
				(*c*)	—	13.6	—	1.27	1.08	4.33	0.20	7.36	10.28	1.17	24.6
		Trial I		(*a*)	81.05	18.95	1.38	1.75	1.13	7.49	0.71	7.45			
	16 weeks	*Capstick*	17.5"	(*b*)	—	59.1	7.0	62.7	52.9	64.1	63.4	58.4			
		Jan., 1940		(*c*)	—	11.2	0.10	1.10	.6	4.8	0.45	4.35	10.22	0.85	18.95
		Trial II		(*a*)	79.63	20.37	2.13	2.23	1.94	6.72	0.28	9.03			
Guatemala grass	6 weeks	*Silk & Wills*	10"	(*b*)	—	52.2	21.03	58.44	54.32	60.19	46.78	52.15			
		Sept. 22, 1941		(*c*)	—	10.4	0.45	1.30	1.05	4.05	0.13	4.71	9.46	1.18	20.37
		Trial III		(*a*)	73.66	26.34	3.29	2.13	1.75	8.73	0.37	11.83			
	8 weeks	*Silk & Wills*	12"	(*b*)	—	48.18	12.41	47.19	41.61	59.32	50.12	49.94			
		Oct. 6, 1941		(*c*)	—	12.69	.41	1.01	0.73	5.18	0.19	5.91	10.69	0.87	26.34
		Trial I		(*a*)	83.23	16.68	2.38	1.27	—	4.92	0.28	7.83			
	9 weeks	*Maule*		(*b*)	—	59.0	43.0	64.0	—	62.0	45.0	61.0			
		March, 1930		(*c*)	—	9.80	1.02	0.8	—	3.05	0.13	4.8	7.15	—	16.68
		Trial II		(*a*)	82.7	17.3	—	1.9	1.7	5.13	0.23	8.42			
Elephant grass	—	*Walker*	11.39"	(*b*)	—	57.3	—	65.0	49.4	58.9	66.6	54.2			
		March, 1940		(*c*)	—	9.9	—	1.23	.84	3.02	0.15	4.6	9.10	1.04	17.3
		Trial III		(*a*)	80.19	19.81	2.7	1.49	1.14	6.91	0.35	8.37			
	7 weeks	*Silk & Wills*		(*b*)	—	63.4	41.9	60.2	52.0	71.6	60.2	64.2			
		Sept. 30, 1941		(*c*)	—	12.58	1.13	0.90	0.59	4.94	0.21	5.38	10.9	.75	19.8
		Trial I		(*a*)	67.60	32.40	1.70	2.93	—	9.89	0.49	17.40			
	Mature	*Maule*		(*b*)	—	60.0	30.0	56.0	—	58.0	44.0	66.0			
Sugar Cane (Uba)		Feb., 1930		(*c*)	—	19.44	.57	1.64	—	5.7	0.21	11.5	15.5	—	32.40
	Mature	Trial II		(*a*)	76.6	23.4	1.47	2.4	1.4	7.5	0.59	12.8			
		Walker		(*b*)	—	60.7	—	57.6	47.9	58.4	51.1	65.7			
		April, 1940		(*c*)	—	14.2	—	1.38	0.67	4.38	0.29	8.4	14.6	1.03	23.4
		Trial I		(*a*)	72.4	27.6	1.67	1.32	—	9.28	0.49	14.86			
	Mature	*Maule*		(*b*)	—	58.0	39.0	46.0	—	62.	51.	59.			
Cane tops		March, 1930	24"	(*c*)	—	16.0	0.65	0.6	—	5.75	0.25	8.77	11.3	—	27.6
	Mature	Trial II		(*a*)	—	25.3	1.5	1.26	0.7	8.1	0.64	13.4			
		Walker		(*b*)	—	56.2	—	47.7	52.0	59.0	52.0	59.8			
		April, 1940		(*c*)	—	14.2	—	0.6	0.35	4.78	0.34	8.0	14.4	0.5	25.3
		Trial I		(*a*)	73.9	26.1	2.24	1.94	1.68	9.23	0.60	12.1			
Young Cane B 3013	5 Months	*Silk & Wills*	23.90"	(*b*)		59.1	41.7	56.2	52.3	65.3	56.9	58.2			
		Aug., 1941		(*c*)		14.9	0.93	1.09	0.88	6.03	0.34	7.04	13.15	0.99	26.1
		Trial I		(*a*)	78.55	21.45	2.92	2.13	1.11	7.45	0.28	8.67			
Guinea grass	9 Weeks	*Capstick*		(*b*)	—	47.9	—	58.0	37.9	54.7	60.3	48.5			
		Jan., 1940		(*c*)	—	10.25	—	1.23	0.41	4.02	0.17	4.11	8.69	0.90	21.45
		Trial I		(*a*)	60.93	39.87	3.33	3.52	—	10.42	0.64	21.16			
Savannah grass	Young Cut	*Hobbs*		(*b*)	—	52.89	21.8	50.2	—	54.7	83.7	83.9			
		Feb., 1931		(*c*)	—	21.1	1.	1.77	—	5.7	0.54	17.7	21.84	—	30.87
		Trial I		(*a*)	78.1	21.9	2.38	2.81	2.15	5.89	0.61	10.21			
Sweet Potato Vines	4 months	*Capstick*		(*b*)	—	56.1	—	65.1	59.3	36.1	75.0	72.3			
		Feb., 1940		(*c*)	—	12.3	—	1.83	1.27	2.13	0.46	7.38	12.08	1.55	21.9
		Trial I		(*a*)	80.37	19.63	2.42	3.02	2.60	7.06	0.33	6.79			
	3 months	*Silk & Wills*	26.8"	(*b*)	—	52.49	32.12	62.88	58.18	56.14	47.55	51.50			
Velvet bean		Sept., 1941		(*c*)	—	10.30	1.24	1.90	1.51	3.96	0.16	3.50	8.42	1.71	19.63
	9 months	Trial II		(*a*)	75.82	24.18	1.96	3.96	3.47	9.83	0.36	8.06			
		Silk & Wills	30+	(*b*)	—	51.62	25.3	63.3	60.00	52.75	38.15	52.59			
		Sept., 1941		(*c*)	—	12.50	0.5	2.51	2.08	5.10	0.14	4.24	9.4	2.3	24.18
		Trial I		(*a*)	84.05	15.95	2.56	3.09	2.39	4.28	0.40	5.63			
Woolly pyrol	6 weeks	*Silk & Wills*	12.15"	(*b*)	—	64.60	19.61	82.1	78.5	71.5	50.7	71.2			
		Nov., 1941		(*c*)	—	10.30	0.5	2.54	1.88	3.06	0.20	4.00	10.27	2.21	15.95
	3 months	Trial II	25.21" V.B.	(*a*)	75.5	24.5	3.9	3.26	2.76	8.70	0.39	8.26			
50% Velvet bean and Guatemala grass		*Silk & Wills*		(*b*)	—	59.13	50.8	67.8	63.8	64.2	57.6	54.5			
	2 months	Aug., 1941	18.59" G.G.	(*c*)	—	14.42	2.0	2.21	1.76	5.59	0.22	4.50	10.93	1.99	24.5
	6 weeks	Trial I	11.41" W.P.	(*a*)	82.3	17.7	2.97	2.34	1.97	5.22	0.60	6.86			
50% Woolly pyrol and Guatemala grass	2 months	*Silk & Wills*		(*b*)	—	62.0	30.0	74.7	70.5	74.3	55.2	60.4			
		Aug., 1941	15.73" G.G.	(*c*)	—	11.0	0.9	1.75	1.40	3.90	0.34	4.14	9.97	1.57	17.7
	6 weeks	Trial I	15.03" W.P.	(*a*)	79.00	21.0	2.86	2.64	2.23	7.06	0.35	8.04			
50% Woolly pyrol and Elephant grass	6 weeks	*Silk & Wills*		(*b*)	—	62.0	44.3	69.5	66.0	69.2	43.7	60.4			
		Sept., 1941	15.03" E.G.	(*c*)	—	13.0	1.26	1.83	1.47	4.9	0.15	4.86	11.06	1.65	21.00
	9 months	Trial I	30" V.B.	(*a*)	77.6	22.4	2.3	2.74	2.27	8.60	0.32	8.33			
50% Velvet bean and Elephant grass	6 weeks	*Silk & Wills*		(*b*)	—	51.50	23.9	57.9	52.9	55.5	39.4	53.40			
		Sept., 1941	9.84" E.G.	(*c*)	—	11.60	0.60	1.60	1.20	4.80	0.13	4.50	9.08	1.40	22.4

condition for a few days. Although it is known that wilting appreciably lowers the digestibility of the nutritive constituents, this depreciation may be compensated, at least partially, by an increase in digestibility as a consequence of an anticipated greater consumption of dry matter (which would approach the accepted temperate climate standard).

One preliminary trial was carried out in wilting a green fodder and then comparing its digestibility with the figures secured from the same fodder fed in fresh condition. It was necessary to conduct this experiment in dry weather, because the great daily variation in humidity during the rains made the wilting method unsatisfactory for accurate digestibility experiments. However, the wilting of fodder in the shade, even during the rainy season, should be a feasible and satisfactory method for ordinary feeding. The experiment carried out in the dry weather produced a heavy wilt in two days. Analyses showed that by this means it was possible to raise the dry matter of the grass from the normal figure of about 20 per cent. up to about 30 per cent. . . 150 lbs. of fresh grass fodder yielding about 100 lbs. of wilted fodder after two days exposure. The results of the trial were as follows :

	Fresh.	*Wilted.*	
(A) Elephant Grass	17.3% d.m.	31 % d.m.	containing S.E. 11.8 and P.E. 1.66 lb. per 100 lb. of fodder. Dry matter consumed daily per 100 lb. liveweight—2.46 lb. (4 animals).
(B) Para Grass	24.6% d.m.	42.9% d.m.	containing S.E. 16.1 and P.E. 1.97 lb. per 100 lb. of fodder. Dry matter consumed daily per 100 lb. liveweight—2.65 lb. (4 animals).

Thus more than the theoretical dry matter requirement for maintenance was eaten, and its nutritive content was great enough to provide for production also.

The digestibility trials conducted with these wilted fodders (trials which incidentally are not included in the Table) showed that the digestibility of the nutritive constituents was decreased by only 3 per cent. to 5 per cent. ; while the digestibility of the crude fibre was reduced by some 15 per cent. The results are considered sufficiently encouraging to merit further and more elaborate trials, especially ones in which the groups of cattle receiving fresh and wilted material would be interchanged in the middle of the experiment, a measure which was not adopted in this preliminary trial.

Another problem demanding attention is by what means can we grow, use, and store fodders of protein-rich dry matter, such as Woolly pyrol (*Phaseolus mungo*), Soya bean, Sunnhemp, Velvet bean, and other annual legumes which flourish on fertile lands in the tropics. They could be sown successively, cut green, and combined with the fodder to raise the protein equivalent. But we have to recognise that they do best in the "growing season" and will be available only for the latter half of the wet season and for a short time after the rains end. Hay cannot be made from these crops, but velvet beans and canavalia will persist for some time after the dry season has set in. Also it has to be considered how the surplus of young grass fodders grown in the " rainy " season may be cut at the optimum time and kept for the " dry " season when standing fodders are scarce. Protein-rich silage would be of use to dairy husbandmen to reinforce the protein fraction in the fodders cut in the dry season, which are then relatively poor in protein. It might be valuable also to pig and poultry keepers. The process of " ensilage " is therefore considered worthy of investigation under tropical conditions. Silage-making was adopted in Trinidad a number of years ago by some progressive dairies, but was given up as being economically unsound. But since that date the technique has been greatly improved, partly by the use of molasses, or even of mineral acids, to ensure an early acidity in the silage; and partly by the establishment by experiment of the important points relating to the actual manner of constructing and filling a silo.

However, silage-making is by no means without its disadvantages. The filling of the silo must be carried out very carefully if satisfactory results are to be obtained. The losses inherent with the process are always considerable (as indeed they are also in making hay). With great care under experimental conditions and with a good silo, it is said that these losses can be kept down to 15 per cent. or even 10 per cent. But in practice, and especially with the only form of cheap silo, *i.e.* a pit, they easily mount to a much higher figure, even to 30 per cent. The main factor which makes ensilage worth-while in temperate climates, in spite of these drawbacks, is that it provides a means of storing, in a moist and palatable form, the food grown during the summer for use during the winter. This advantage is of much less importance in the wet tropics where the provision of green fodder becomes difficult at the end of the dry season only in the districts where this dry season persists longer than three months. And even in these districts green fodder of a kind, admittedly far from perfect but none the less consumable, is easily kept for four months or a little longer in the form of a standing crop of Uba sugar cane, or such a grass as Guatemala.

Of special appeal in the sugar-producing wet tropics is the use of molasses in the production of silage, using finely chaffed material. The process itself, the type of container, the pressure, the material and its condition prior to ensiling in order to make the greatest economic use of the

container . . . all these require detailed study before we can appraise the utility of such silage. However, work on this project has been initiated already, and results should prove of interest and value in determining the most satisfactory, most economic and most feasible method of providing high-protein dry matter fodder during the dry season.

I would express appreciation of the work done by the students mentioned earlier in this paper, and acknowledge the help accorded by the Department of Chemistry at the College, by Captain Metivier, O.B.E., of the Department of Agriculture, Trinidad,and by O. T. Faulkner, Esq., C.M.G.

SOIL STRUCTURE *

We have had many studies of the properties of the colloidal material in the soil. Its behaviour as a colloidal solution has been fairly satisfactorily charted. The nature of its acidity, its base exchange reactions, its flocculation, are well known in a general way. Great strides have also been made toward obtaining a picture of its mineralogical nature and crystal structure.

We do not have as yet, however, satisfactory methods for giving quantitative characterisation to the physical state of soils in the natural field condition. Practical students of soils and soil morphologists have attached great significance to this field state of soils. They have recognised great differences in the productivity of soils having identical amounts and kinds of colloidal material. This difference has been attributed to differences in the arrangement of the particles or to the structure of the soil. The farmer refers to soils as varying in "tilth", good tilth being defined as the optimum physical state for crop growth. It has long been recognised that tilth and structure are definitely associated with the presence of colloidal material. Soils devoid of colloidal material have what is known as single-grain structure. Each grain acts as a unit. No compound particles are present. The soils will vary in physical state only as a result of variations in the closeness of packing of these single grains. Sands and silts are both soils having single-grain structure. Because of the size of the grain, the tilth of sandy soils is seldom bad. They are well-drained, but of course lack the capacity to store moisture. Soils containing very large amounts of silt often present quite a serious structure problem. The individual grains are so small that if they are forced into a position of close packing by beating rains or mechanical pressure, they become exceedingly hard and intractable and very slowly permeable to both air and water. Some of the most difficult soils to manage from the physical point of view are composed largely of fine silt having single-grain structure.

Since structure is associated with the colloidal material, and since compound particle formation of the colloidal material is referred to as flocculation or granulation, early students approached the problem of soil structure or formation of soil granules by a study of the flocculation of clay soils. There are cases, particularly soils with only a medium content of clay, where the mere flocculation of the colloidal material by an electrolyte will be sufficient to convert a soil in unsatisfactory tilth into a soil in good tilth. There are other cases, usually heavy soils, in which all of the colloidal material is in a flocculated state, which are still in exceedingly poor physical condition. This poor condition is connected, in part at least, with the size and nature of the compound particles. The compound particles formed by the flocculation of colloidal clay may contain thousands of primary colloidal particles, but their size may still be very small. Compound particles of minute size can fit so closely together as to give a soil that is practically impervious to both air and water. As an example, it has been found that the C-horizon of the widely distributed Miami Silty-Clay-Loam is ordinarily in the flocculated state. Field studies show that it is practically impervious to water and to the roots of plants. The roots of trees 150 years old have been found to stop abruptly when they reach this horizon, save for an occasional root which found its way through a worm hole or a crack produced by shrinkage during dry weather. This layer has an apparent specific gravity of 2.1 and a pore space of about twenty-two per cent. Even when loosened and exposed to the air, it has a tendency to run together. When subjected to wet sievings it has been found to contain no appreciable amounts of compound particles large enough to be retained by a 100-mesh sieve.

The secondary particles in a soil having good structure are of a different order of magnitude. A high percentage of them will range in size between 1 and 3 millimeters in diameter. They must be essentially flocculated or else they would spontaneously disperse when placed in water. We have come to believe that flocculation is to be regarded as a necessary first step in the granulation process, but *that granulation is much more than flocculation.* It involves the production of much larger units as a resultant of a combination of different factors. Differential stresses set up by wetting and drying, freezing and thawing, the action of roots, etc., produce dense granules with cracks and channels between them. Water, air, and plant roots tend to move through these cracks and channels more readily than through the dense granules. This leads to the deposition at the surface of the granule of various types of material which are capable of acting as cementing agents. Humic acid, colloidal silica, calcium carbonate, the iron and aluminium hydroxides, all probably serve in this capacity under appropriate conditions.

* Extracted from an article by Richard Bradfield and V. C. Jamison, which was published in *Proc. Soil Sci. Soc. America*, Vol. 3, p. 70.

THE EFFECT OF LIGHT ON THE INCIDENCE OF CACAO THRIPS

BY

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Introduction

The cacao thrips, *Selenothrips rubrocinctus* Giard, presents two problems to the economic entomologist.

The first relates to the epidemic outbreaks of the pest which occur at irregular intervals and are its most spectacular feature. Little is known of the causes of these outbreaks. The second problem is provided by the small persistent infestations always to be found in areas under cacao cultivation. These infestations are confined to definite places colloquially known as thrips pockets.

In Trinidad, B.W.I., where the work described below was carried out, cacao is grown under permanent overhead shade provided by the anauca immortel, *Erythrina micropteryx*, and the bocare immortel, *Erythrina glauca*. Observations by both planters and entomologists have made it clear that reduction of this shade is often if not invariably followed by increased infestations. The most obvious effect of the removal of part of the immortel canopy is the increased amount of light that pours uninterruptedly onto the cacao beneath. The regularity with which such a light pocket develops into a thrips pocket has led to the belief that light itself is the deciding factor in the endemic incidence of the pest. The object of the work described below was to investigate the validity of this claim.

Review of Literature

The majority of the earlier and many of the more recent references to this subject are concerned with observations made in the field during general studies of the entire cacao thrips problem. Such observations were usually vague as to statistical and ecological detail. Urich (1911, 1918, 1919), Freeman (1924), Russo (1930, 1936) and Stephenson (1938) noted that in the West Indies absence of shade favoured thrips attack on cacao. Patterson (1923a, 1923b), Cotterell (1927) and Kaden (1929) recorded similar observations in West Africa.

Reyne (1921), in Surinam, attempted to interpret the incidence of thrips in terms of a single deciding factor. This factor was light. Working with thrips populations in the laboratory he found that while immature forms could not be shown to be attracted by light, adults were positively phototactic. When released in a room adults were found to cover distances of over 7 metres to reach the single window of one metre square by which light was admitted. Reyne correlated this positive phototaxism with field observations which showed that a relatively high light intensity in any area was generally associated with heavy incidence of thrips. Severe thrips damage was noticed in unshaded cacao and in fields where the plants were too young to give mutual shade. Heavy pruning of cacao plants and their shade trees was often followed by heavy thrips attack. Finally it was noticed that cacao in its wild habitat, under the shade of tropical rain forest, was never attacked severely, while thrips when observed outside cacao plantations were always found in sunny exposed places. Reyne concluded that in the field the thrips adults were attracted to light areas and bred there. Using this theory as a basis he argued that permanent control measures must involve even shading. Uneven shade would result in thrips migration into the lighter areas where damage would occur.

Reyne's theory ignored the possibility that it was through the cacao plant that the environment affected the thrips. This had been first suggested by Ballou (1915, 1919) who maintained that when cacao trees were physiologically upset they could become more suitable food for the thrips which would then reproduce more rapidly than on healthy trees. This theory was supported by Patterson (1923a, 1923b), Freeman (1924) and Cotterell (1927) who pointed out that improvement in the health of the trees by cultural methods was an important factor in controlling a thrips outbreak. This theory also received support from workers investigating similar problems with other insects.

Davidson (1925) studied the factors influencing the infestation of *Vicia faba* by *Aphis rumicis* L. When infested plants were grown under different light intensities increase in light gave increased incidence of aphids. The use of artificial light in winter caused heavier infestations than on plants receiving normal daylight only. In no case was this increased incidence due to migration to the more illuminated plants. Davidson concluded that increased light caused increase of carbohydrate in the host sap and so accelerated reproduction of the insect.

De Fluiter (1939) in Java observed that *Pseudococcus citri* Risso was more abundant on unshaded than shaded coffee and experiments were carried out to determine the effect of light on the host-pest complex. Young plants were isolated under different light intensities and each was inoculated with mealy bugs. It was found that development to the adult stage was twice as fast in the lighter cages, resulting in an increase in infestation. This increase was attributed to a change in the physiology of the host induced by light.

The results obtained by Davidson and de Fluiter are in conflict with Reyne's theory of phototactic migration as a deciding factor in the incidence of thrips. All agree that light can be a deciding factor but the later work appears to show that under both temperate and tropical conditions light is indirect in its action.

Field Observations

This work was carried out on River Estate in the Diego Martin Valley, on La Montserrat Estate in the Maracas Valley, on the St. Antoine, San Pablo and Hermitage Estates in the San Rafael district, on Non Pareil Estate at North Manzanilla, and on Santa Severa and Corsica Estates in the Brasso district of the Central Range.

Objects

1. To provide statistical evidence on populations of cacao thrips on shaded and unshaded cacao.

2. To obtain evidence to account for any observed differences in populations.

Methods and Apparatus

Surveys were made of thrips populations on shaded and insolated cacao giving numerical data which were then statistically examined. This work was carried out during November and December, 1941, and is summarised in Table I.

In order that any results obtained could be generally applied a survey was planned which included a range of estate practices and of soil and meteorological conditions. It was felt that this dispersal would largely reduce the error due to tree to tree variation in the degree of inherent susceptibility to thrips attack. Five localities were selected: the Diego Martin and Maracas Valleys of the Northern Range, the San Rafael district in the Northern Plain, the North Manzanilla area on the East Coast, and the Brasso district in the Central Range. In each locality 10 sites were chosen making 50 sites in all. The sites were chosen so that each contained 2 stations, one shaded and one insolated. Each station contained 5 to 6 cacao trees. In no site were the 2 stations more than 50 metres apart. At 40 sites the lack of shade at the insolated station was due to failure of immortel shade trees. Six of the remaining 10 were unshaded because of streams, 3 because of roads and one because of exposure at the edge of a field. Shaded stations were under the normal canopy which prevails in Trinidad cacao.

The degree of insolation at each station was measured by a photometer of the rectifier (selenium) cell type. The cell was attached to a small table with a single leg 1.25 metres long and was carried slightly above the level of the head of the operator who walked rapidly to and fro stopping every few paces to record a reading. To minimise the fatigue effect of the cell not more than twelve readings were made in one station and these were integrated into a Light Index for the station. This index is the mean of the readings expressed as a percentage of the value of full sunlight when they were taken. All light measurements were made between 10 a.m. and 2 p.m. when the sun was well overhead and unobscured by clouds. Light indexes were made for the pairs of stations of sites 1 to 45. Unfortunately the photometer was damaged before sites 46 to 50 were surveyed. From experience gained earlier the writer is confident that the light and shade contrasts in these sites were as great as in 1 to 45 and the results from them have been recorded.

The mean light index for the insolated stations was 73 with a coefficient of variability of 12.76 per cent. The corresponding mean for the shaded stations was 18 with a coefficient of variability of 31.05 per cent. The difference of 65 between these means was statistically significant with $P=0.001$. The layout of the survey was such as to allow of its results being statistically treated by "Student's" technique. Each of the 50 sites contained 2 stations, one receiving one treatment in the form of insolation (mean light index=73) while the other received the contrasting treatment of shade (mean light index=18).

The number of thrips was counted on 200 leaves at each site, of which 100 were selected at random from the insolated station and 100 similarly selected from the shaded station. A total of 10,000 leaves were examined of which 5,000 were from 277 insolated trees and 5,000 from 278 trees under shade. The random selection was confined to healthy leaves which had hardened after flushing and which were of average size and normal appearance. All stages of thrips except eggs were included in the counts. Thrips were classified into (1) immature forms including prepupae and pupae and (2) adults. The ratio of the first to the second class is referred to below as the N/A ratio. Owing to the possibility of error it was decided to ignore the ratio values from any site where the population of either the shaded or the insolated station was less than 10 thrips per 100 leaves. All counts were made by the writer or by a trained assistant.

Results

The first object in providing statistical evidence on thrips populations in shaded and unshaded areas was attained. Table I shows that the 5,000 leaves in the insolated stations had a population of 10,951 thrips or a mean of 219 per 100 leaves. The 5,000 leaves under shade had 1,519 thrips or a mean of 30 per 100 leaves. Statistical analysis by "Student's" technique showed that thrips infestations were significantly heavier on insolated cacao with $P=0.001$.

The second object in providing evidence to account for these heavier infestations was partially attained. The mean of the N/A ratio for the insolated stations was 3.03. That of the shaded stations was 2.16. Statistical analysis by "Student's" technique showed that this ratio was significantly smaller under shade, with $P=0.05$. The greater proportion of immature forms to adults under insolated conditions conflicts with Reyne's theory of adult migration as a cause of heavier infestations in unshaded areas. If his theory is correct the proportion of adults on exposed cacao should be higher than under the surrounding shade. The reverse is the case. The higher proportion of immature forms where shade is absent suggests that there reproduction is more rapid. This higher reproductive rate would adequately account for the greater populations observed and Reyne's theory is unnecessary to explain the occurrence of heavier infestations.

Table I

Locality.	No. of Site.	Insolated Stations. No. of Trees.	Light Index	Thrips per 100 Leaves. N	A	Total.	N/A	Shaded Stations. No. of Trees.	Light Index	Thrips per 100 Leaves. N	A	Total.	N/A
	1	5	68	10	20	30	0.50	5	14	10	2	12	5.00
	2	4	65	41	21	62	1.95	6	15	0	19	19	0.00
Diego Martin	3	5	85	57	26	83	—	6	15	0	0	0	—
	4	4	86	2	9	11	—	5	14	0	0	0	—
Valley,	5	4	83	81	29	110	2.79	6	25	6	12	18	0.50
	6	4	90	22	34	56	0.65	5	20	19	22	41	0.86
Northern	7	6	68	163	40	203	4.08	6	23	6	9	15	0.67
	8	4	72	103	59	162	—	5	17	0	1	1	—
Range.	9	5	75	37	7	44	5.29	5	19	6	6	12	1.00
	10	6	75	32	18	50	1.78	5	19	3	10	13	0.30
	11	5	72	173	47	220	3.68	5	20	30	33	63	0.91
	12	5	63	226	69	295	3.28	5	27	31	16	47	1.94
	13	5	71	160	52	212	3.08	4	21	20	18	38	1.11
San Rafael,	14	4	57	71	46	117	1.54	5	17	38	34	72	1.12
	15	5	63	114	50	164	2.28	5	13	20	7	27	2.86
Northern	16	6	73	109	38	147	2.87	6	13	10	12	22	0.83
	17	6	80	84	49	133	1.71	6	20	6	9	15	0.67
Plain.	18	5	80	76	37	113	—	5	20	0	2	2	—
	19	6	81	94	32	126	2.94	5	19	12	4	16	3.00
	20	5	70	77	39	116	—	5	20	1	3	4	—
	21	8	60	180	51	231	3.53	7	10	78	20	98	3.90
	22	6	57	394	85	479	4.64	7	24	13	9	22	1.44
	23	6	53	98	25	123	3.92	6	24	22	12	34	1.83
Brasso,	24	7	90	53	17	70	3.12	5	29	87	12	99	7.25
	25	6	76	169	39	208	4.33	5	14	29	3	32	9.67
Central	26	5	80	62	60	122	1.03	7	20	15	8	23	1.88
	27	5	75	145	69	214	2.10	6	15	11	12	23	0.92
Range.	28	5	70	252	89	341	2.83	5	10	16	15	31	1.07
	29	5	75	118	65	183	1.82	5	10	14	22	36	0.64
	30	6	71	143	63	206	2.27	5	14	1	11	12	0.09
	31	8	77	80	55	135	1.45	6	18	1	11	12	0.09
	32	5	72	51	33	84	—	5	11	0	2	2	—
Maracas	33	6	78	138	48	186	2.88	6	17	3	10	13	0.30
	34	5	89	161	45	206	3.58	5	16	28	4	32	7.00
Valley,	35	6	95	147	46	193	3.20	4	20	4	9	13	0.44
	36	5	67	284	42	326	6.76	5	17	28	3	31	9.33
Northern	37	6	70	428	121	549	3.54	6	25	147	30	177	4.90
	38	6	74	110	35	145	3.14	6	16	19	7	26	2.71
Range.	39	6	70	241	53	294	4.55	6	15	33	9	42	3.67
	40	6	77	385	122	507	3.44	6	23	8	5	13	1.60
	41	6	57	755	239	994	3.16	6	17	76	72	148	1.06
	42	6	67	659	126	785	5.23	6	11	15	33	48	0.45
North	43	6	75	988	204	1,192	4.84	6	14	25	36	61	0.69
	44	6	75	61	38	99	—	6	21	1	2	3	—
Manzanilla,	45	6	78	42	33	75	1.27	6	39	9	5	14	1.80
	46	6	Photo-	70	39	109	—	6	Photo-	2	0	2	—
East Coast.	47	6	meter	68	45	113	—	6	meter	1	0	1	—
	48	6	—	88	65	153	—	6	—	3	5	8	—
	49	6	dama-	7	12	19	—	6	dama-	0	2	2	—
	50	6	ged	118	38	156	3.11	6	ged	10	14	24	0.71
Totals		277	3,305	8,227	2,724	10,951	118.16	278	821	917	602	1,519	84.21
Means		5.54	73	165	54	219	3.03	5.56	18	18	12	30	2.16

N=Immature stages including prepupae and pupae. A=Adults.

Greenhouse Experiments

The two experiments described below were carried out in a small greenhouse situated at the Imperial College of Tropical Agriculture, St. Augustine. This greenhouse was partially sunken in the ground and measured 6 metres by 3 metres in ground plan. Its long axis ran approximately east and west. The glass roof was whitewashed on the inside and on the outside was protected by wire netting supported 15 cms. from it. Inside were two longitudinal shelves separated by a central floor. A sprinkler was fitted in the roof which could give a spray of atomized water. By its use the relative humidity of the air was kept above 70 per cent. throughout the experiments.

Clonal cacao of the variety I.C.S.1 was used. The plants were cuttings from the College Botanical Department and were potted up with a uniform mixture of soil and compost into split bamboo baskets all of the same size and shape. After potting the plants were hardened off under uniform conditions of shade and management. When about 6 weeks old they were transferred to the greenhouse.

First Greenhouse Experiment

This experiment was carried out from October, 1941 to February, 1942. Clonal cacao was grown under uniform conditions of soil, management and climate except for controlled variation in light intensities. Thrips populations were introduced and studied.

Objects

1. To find out if thrips populations were affected by light.
2. If they were affected to provide evidence on the method of action of light.
3. To provide evidence on thrips damage under different light intensities.

Design and Management

Owing to lack of space only three treatments were arranged. These were a light treatment, an intermediate treatment and a shade treatment. It was not found possible to provide for treatment replications, and the design was such as to preclude statistical analysis of the results. This handicap was less serious than would at first appear. Owing to the uniformity of all other conditions any observed population differences may be assumed to have been due to the differences in treatment.

The eastern half of the roof was shaded by stitching black cloth on the wire netting. The western half was left uncovered with the whitewash and netting wire untouched. The western third of the house was now called the light treatment, the middle third the intermediate treatment, and the eastern third the shade treatment. Using a rectifier cell photometer twenty-four light measurements were made in each treatment. These measurements were made between 11 a.m. and 12 noon when the sun was unobscured and were integrated into light indexes as described in the section on Field Observations. The light indexes of the three treatments were 50, 33 and 11 with coefficients of variability of 7.9, 26.8 and 35.8 per cent.

These treatments were not completely satisfactory. The intensity of the light treatment could have been increased without harming the plants. The intermediate treatment, as only half the roof over it was shaded, showed a large daily variation. In the morning the plants were shaded. As the sun moved west, the shade moved east and by 4 p.m. the plants were receiving as much light as the light treatment. The shade treatment was too dark and the plants showed signs of physiological upset in the form of leaf scorch and premature leaf fall.

On October 13, 48 plants were placed in the house, 16 in each treatment. The plants were numbered 1 to 48 and Diagram I illustrates their positions in the house.

Meteorological observations were made within the house with two recording thermo-hygrographs and two Piché evaporimeters. The former were screened from direct radiation and placed on the

Diagram I

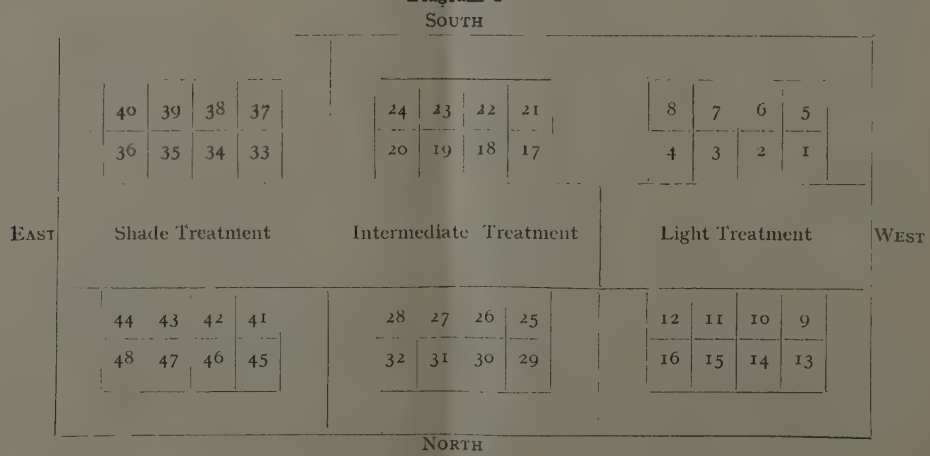
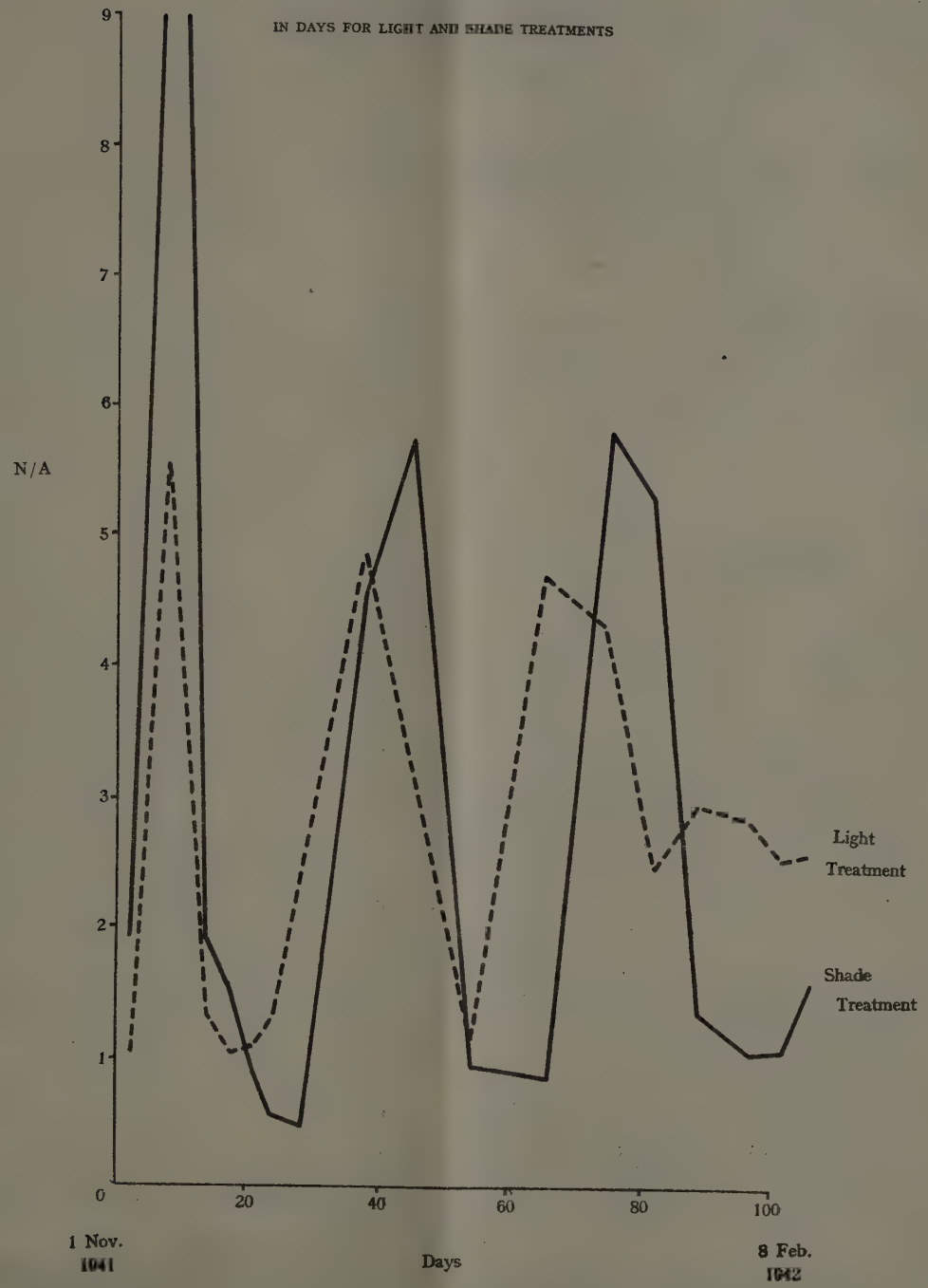


FIG. 1.

FIRST GREENHOUSE EXPERIMENT

N/A PLOTTED AGAINST DURATION OF EXPERIMENT

IN DAYS FOR LIGHT AND SHADE TREATMENTS



shelves in various positions. The latter were hung from the roof, one in the light treatment and one in the shade, with the filter paper discs 15 cms. above the plants.

The thermographs showed little difference in air temperature throughout the house. The mean daily maximum for the light treatment was 31.1°C while that of the shade treatment was 30°C. The corresponding minima were 22.8°C and 23.2°C. The hygrographs and Pichè evaporimeters showed no difference in the relative humidity and evaporating power of the air throughout the house.

The plants in the light treatment flushed more often and more vigorously than those under shade. This was true to a lesser extent of the intermediate treatment. In order that leaf area of plants receiving more light should not increase out of proportion to the others many of the buds and young leaves were removed.

During the last fortnight of October each plant was inoculated by hand with 100 thrips pupae. In addition 200 adults were released among the plants in each treatment. These thrips were obtained from the leaves of Cashew, *Anacardium occidentale*, a host plant on which the pest was found in quantity. This change of host did not have any adverse effect on the results of the experiment. The inoculations were but moderately successful. On November 3, 39 thrips were counted in the light, 22 in the intermediate and 61 in the shade treatment. It was decided to refrain from further inoculations and to allow larger populations to build up from these small colonies.

From November 3 until February 14 population counts were made. During November counts were made every three or four days but as the populations increased in December, January and February the intervals lengthened to seven or ten days. Immature forms including prepupae and pupae, and adults were counted separately so as to provide information on the ratio of immature forms to adults (N/A ratio). While the populations were small the leaf area was in excess of the requirements of the thrips. By January 5 the populations were sufficiently large to make it necessary to express them in terms of the leaf areas which they were occupying, and all subsequent counts were associated with estimates of leaf areas made in the manner described by Stephenson (1938). The greatest length was multiplied by its greatest breadth and the approximate area derived by multiplying this product by 2/3.

On February 6 an assessment was made of thrips damage in the light and shade treatments as shown in Table III. The experiment was ended on February 14 when thrips damage in the light treatment was such that many leaves had fallen or were about to fall. At the same time the plants under shade were in an unsatisfactory condition due to lack of light, one having died.

Results

The first object was attained. Table II shows that the thrips populations were affected by the light factor. On November 3 the shade treatment had the greatest population with a total of 61 thrips, those of the light and intermediate treatments being 39 and 22 thrips respectively. At the end of the experiment on February 14 the light, intermediate and shade totals were respectively 706, 342 and 186 thrips per square metre. Despite the original population discrepancies which favoured the shade treatment, the light factor effected a complete change in the relative size of the treatment populations. The incidence of thrips in the greenhouse became a direct expression of prevailing light intensities.

The second object, which was to provide evidence on the method of action of the light factor, was attained. It was shown that thrips development was more rapid in the light treatment than in the shade. In Figure 1 the N/A ratios for each count as given in Table II are plotted against the duration of the experiment in days. Curves for the light and shade treatments only were given. These curves have a series of maxima and minima showing a periodic distribution, the periodicity of the shade curve being longer than that of the light. The early populations contained a preponderance of young adults. These adults oviposited more frequently at first than later in life giving a maximum of eggs, followed by a maximum of immature forms which matured to give a second maximum of adults, and so on. The N/A ratios therefore increased and decreased periodically, the lengths of the periods being directly proportioned to those of the life cycles. The longer period of the shade treatment curve means that the thrips in this treatment had a longer life cycle. This is important since it confirms the inference made from the N/A ratios provided by the field counts, which was that thrips reproduction was more rapid in insolated areas than under shade.

Assessment of thrips damage showed that by the standards of field practice the cacao in the light treatment suffered more than 20 times as much as that under shade. This assessment is summarised in Table III. In the light treatment 21.46 per cent. of the leaves fell into the classes of severe and very severe damage as compared with 0.94 per cent. in the shade treatment. Slight to moderate damage is of little importance from the economic point of view but severe damage especially if it results in leaf fall has serious consequences. That over 20 per cent. of the leaves in the light treatment showed such a degree of damage as compared with 1 per cent. under shade indicates the harm that may result to cacao from thrips attack due to excessive light.

Second Greenhouse Experiment

This experiment was carried out during February, 1942.

Objects

To determine the extent of migration of thrips adults from plants under shade to plants receiving more light.

Design and Management

All conditions of soil, climate and management were the same as for the first experiment. On February 16 the plants from the shade treatment

Table II

Date of Count.	Light Treatment Light Index=50 16 Plants			Intermediate Treatment Light Index=33 16 Plants			Shade Treatment Light Index=11 16 Plants		
	Total No. of Thrips	Population per Sq. Metre	N/A	Total No. of Thrips	Population per Sq. Metre	N/A	Total No. of Thrips	Population per Sq. Metre	N/A
3 Nov., 1941 ...	39		1.05	22		1.75	61		1.90
5 Nov., 1941 ...	67		3.79	26		2.71	64		8.14
8 Nov., 1941 ...	85		5.54	47		14.67	88		28.33
11 Nov., 1941 ...	81		3.05	42		5.00	62		9.33
14 Nov., 1941 ...	75		1.34	49		2.50	58		1.83
18 Nov., 1941 ...	79		1.03	51		2.00	48		1.58
21 Nov., 1941 ...	102		1.10	56		1.00	52		0.93
24 Nov., 1941 ...	65		1.32	45		2.21	34		0.55
28 Nov., 1941 ...	114		2.35	43		2.58	34		0.48
1 Dec., 1941 ...	98		3.22	39		5.50	36		2.27
8 Dec., 1941 ...	161		4.82	54		12.50	71		4.46
15 Dec., 1941 ...	206		2.91	34		0.89	74		5.73
24 Dec., 1941 ...	263		0.99	26		0.30	82		0.95
5 Jan., 1942 ...	591	246	4.68	71	34	2.09	44	45	0.83
14 Jan., 1942 ...	968	403	4.29	174	82	3.14	116	119	5.82
21 Jan., 1942 ...	744	309	2.43	228	128	2.21	170	170	5.30
28 Jan., 1942 ...	1,089	475	2.96	272	158	1.92	161	152	1.37
5 Feb., 1942 ...	1,479	646	2.86	387	225	2.10	170	161	1.05
10 Feb., 1942 ...	1,821	787	2.53	578	324	2.00	145	156	1.04
14 Feb., 1942 ...	1,633	706	2.57	664	372	2.61	173	186	1.58

Table III

Class.	Percentage of Leaves in Each Class.	
	Light Treatment.	Shade Treatment.
No Damage	5.76	9.43
Trace of Damage	29.32	29.25
Slight Damage	26.18	46.22
Moderate Damage	17.28	14.16
Severe Damage	13.61	0.94
Very Severe Damage, Sufficient to cause Leaf Fall ...	7.85	0.00

and the eight plants in the eastern half of the intermediate treatment were removed from the house. The 16 plants in the light treatment were then transferred to the shade treatment with their thrips populations undisturbed. All thrips were then removed from the eight plants in the western half of the intermediate treatment, which were receiving almost as much light as the light treatment, and were carrying over 450 thrips. They were then arranged in the light and intermediate treatments, four on each shelf spaced at intervals of one metre, the most easterly being one metre from the plants in the shade treatment. The plants had the same numbers as in the first experiment and their positions are illustrated in Diagram II.

Counts were made daily of adult thrips that migrated to the eight depopulated plants from the shade treatment. The plants in the shade treatment suffered severely, one dying and the remainder losing many leaves. This was due to thrips damage already sustained and to the excessive shading of their new positions. The experiment was brought to an end of February 21.

Results

No response was shown to the light stimulus by the adult thrips. The results are given in Table IV.

On February 17, 20 adults had migrated to the exposed trees. Four days later this total had only increased by 9 and the majority of the adults were still under shade. The shade treatment total at the beginning was 457 adults and 5 days later it was 347. Of the 110 missing thrips, migration accounted for 29 and the remaining 81 could not be traced. It was known that heavy mortality occurred under shade due to abnormal leaf fall and this was sufficient to account for the absent thrips. During the survey of the shade treatment made on February 21 it was observed that the 347 thrips adults had crowded together on the reduced leaf area rather than migrate to more highly illuminated trees. Such migration as did occur may be accounted for by the population pressure gradient that existed. It must be concluded that light played little or no part in any thrips migration that occurred. Since Reyne's theory of adult migration as a phototactic response

Diagram II

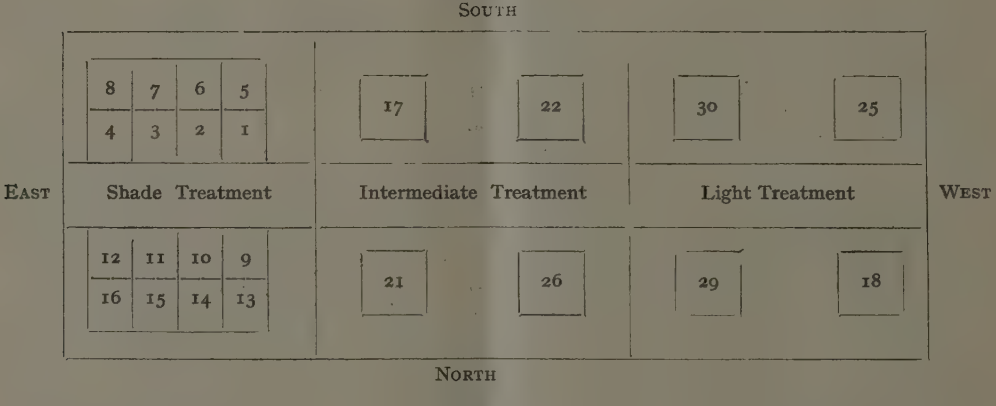


Table IV

Date of Count.	Shade Treatment Plants 1 to 16.	Light and Intermediate Treatments.				
		Trees 17 and 21	Trees 22 and 26	Trees 30 and 29	Trees 25 and 18	Total.
14 February	*457 adults					
17 ,, ...	—	8 adults	4 adults	6 adults	2 adults	20 adults
18 ,, ...	—	11 ,,	5 ,,	9 ,,	2 ,,	27 ,,
19 ,, ...	—	10 ,,	3 ,,	10 ,,	2 ,,	25 ,,
20 ,, ...	—	9 ,,	3 ,,	10 ,,	2 ,,	24 ,,
21 ,, ...	347 adults	11 ,,	6 ,,	9 ,,	3 ,,	29 ,,

* Obtained from the last count of the first experiment.

was based on laboratory evidence, and since the conditions of this experiment more closely resemble those of the field than the laboratory, it appears probable that light is of equally small importance in its effect on thrips movement in the field.

Food Preference Tests

Methods

This work was carried out from October, 1941, to February, 1942. Laboratory studies were made of the preferences shown by thrips nymphs of the first and second stages for cacao leaves from different sources. The method used was that described by Stephenson (1938). Discs 5 cms. in diameter were cut from the leaves and placed adjacent to each other on damp blotting paper with the upper surface of the disc uppermost. Each disc was then inoculated with the same number of nymphs, the whole covered with a large inverted petri dish and kept in the dark to obviate any stimulus from light. The subsequent distribution of the nymphs was regarded as an indication of their preferences for the leaves being tested. The nymphs were obtained from cashew, *Anacardium occidentale*, and were transferred to the leaf discs by a damp camel hair paint brush. During transfer the brush was placed below the abdomen and excrement drop and the nymph then lifted gently. Very small and very large nymphs were not used. The delicate nature of the former made them liable to injury during transfer while the latter were too near the third or prepupae stage in which feeding does not occur. After inoculation the nymphs wandered freely and rapidly for some hours over the discs, the blotting paper and the inside of the petri dish. Subsequently they settled down on the discs and commenced feeding. The totals recorded below were the sum of two counts of the number of thrips on each disc made 24 and 48 hours after the beginning of each test.

Series I

The three tests in this series were made in January and February, 1942, to determine the uniformity among the I.C.S.1 cuttings in the College propagator from which the plants of the greenhouse experiments had been selected. The tests involved nine plants designated A to I, three in each test. Three or four leaves which had hardened after flushing and were of the same age were taken from each plant. The discs cut from these leaves were arranged in duplicated latin squares laid out under separate petri dishes. Each disc was inoculated with 10 nymphs.

Test 1

B 21	C 0	A 7	C 8	A 10	B 5
A 6	B 9	C 3	B 7	C 12	A 4
C 5	A 21	B 3	A 5	B 3	C 18

Treatment Totals :—A=53 ; B=48 ; C=46.

Test 2

D 3	F 2	E 16	F 12	E 19	D 10
E 20	D 2	F 5	D 21	F 5	E 14
F 11	E 7	D 21	E 7	D 6	F 19

Treatment Totals :—D=63 ; E=83 ; F=54.

Test 3

I 5	H 40	G 24	H 13	G 3	I 16
G 5	I 2	H 23	I 4	H 2	G 7
H 16	G 10	I 28	G 4	I 45	H 22

Treatment Totals :—G=53 ; H=116 ; I=100.

In none of these three tests were the differences between the three totals significant.

Series II

The five tests in this series were made with material from the plants undergoing the three treatments in the first greenhouse experiment. (Light Treatment=L, Intermediate Treatment=I, Shade Treatment=S.) Three or four leaves of the same age which had hardened after flushing were selected at random from each treatment. The discs were arranged in replicated latin squares, each square being laid out under a separate cover. The number of nymphs with which each disc was inoculated varied from test to test.

Test 1

October 14 to 16, 1941, after the plants had been in the greenhouse for 24 hours ; 20 nymphs per disc.

L 1	I 3	S 3	S 1	L 0	I 2
I 14	S 1	L 35	I 14	S 14	L 17
S 8	L 5	I 4	L 20	I 15	S 1

Treatment Totals :—L=78 ; I=52 ; S=28.

The differences between these totals were not significant.

Test 2

October 22 to 24, 1941 ; 10 nymphs per disc.

L 8	I 1	S 8	I 0	S 0	L 18
S 1	L 3	I 0	L 11	I 2	S 4
I 2	S 1	L 9	S 1	L 3	I 1

Treatment Totals :—L=52 ; I=6 ; S=15.

The following differences are significant by "t" test :—

48, P=0.01.

29, P=0.05.

Test 3

October 29 to 31, 1941 ; 15 nymphs per disc.

S	L	I		L	I	S		
1	12	5		9	1	3		
I	S	L		S	L	I		
25	1	33		5	23	0		
L	I	S		I	S	L		
18	21	0		1	0	23		

Treatment Totals :—L=118 ; I=53 ; S=10.

The following differences are significant by "t" test :—

125, P=0.01.
75, P=0.05.

Test 4

November 5 to 7, 1941 ; 15 nymphs per disc.

L	I	S		I	S	L		S	L	I
15	1	0		14	0	10		0	36	4
S	L	I		L	I	S		I	S	L
0	30	0		40	2	1		14	1	15
I	S	L		S	L	I		L	I	S
6	0	14		0	8	1		18	5	0

Treatment Totals :—L=186 ; I=47 ; S=2.

The following differences are significant by "t" test :—

132, P=0.01.
88, P=0.05.

Test 5

December 10 to 12, 1941 ; 12 nymphs per disc.

I	S	L		S	L	I		L	I	S
4	3	11		1	5	17		5	8	1
L	I	S		I	S	L		S	L	I
38	17	2		11	3	9		4	23	4
S	L	I		L	I	S		I	S	L
1	18	7		10	15	4		8	4	19

Treatment Totals :—L=138 ; I=91 ; S=23.

The following differences are significant by "t" test :—

93, P=0.01.
62, P=0.05.

Series III

The ten tests in this series were carried out with leaf material from 10 trees in the five localities selected for survey in the field observations, 2 trees being chosen from each locality. In each test a comparison was made between leaves growing on an insolated branch and those on a shaded branch of the same tree. Nine healthy leaves of the same age were taken from each branch and one disc was cut from each leaf. The 18 discs so obtained were arranged in two squares as shown below, each square being laid out under a separate cover.

L	S	L		S	L	S		
S	L	S		L	S	L		
L	S	L		S	L	S		

L=discs from insolated leaves.
S=discs from shaded leaves.

Each disc was inoculated with 10 nymphs and after 24 and 48 hours counts were made. These counts were integrated into totals for the nine discs of each treatment, which are given in Table V.

When analyses statistically the mean difference of 113.5 between these totals proved to be significant with P=0.001.

Results

The tests in series I showed that I.C.S.1 clonal material from the propagator was uniformly attractive, three tests involving nine plants having failed to reveal any significant differences in attractiveness to thrips nymphs.

The tests in series II showed that light could render cacao leaves more attractive to thrips nymphs than leaves kept under shade. The first test, the material for which had been undergoing the light, intermediate and shade treatments for 24 hours, revealed no significant differences in attractiveness. Tests 2 and 3, made several days later, showed that the light treatment had become significantly more attractive than the intermediate and shade treatments at P=0.05, but did not show a significant difference between these last treatments. Test 4, made some two weeks later, showed a significant difference between the light and shade treatments at P=0.01. The difference between the light and intermediate treatments was significant at P=0.05, while that between the intermediate and shade treatments was not significant. Test 5, made a month later, showed no significant difference between the light and intermediate treatments, but revealed that the latter was significantly more attractive than the shade treatment at P=0.05. The light treatment remained more attractive than the shade at P=0.01.

The results from the 10 tests in series III confirmed those of series II. Evidence was obtained that in the field lack of shade increased the attractiveness of cacao leaves to thrips nymphs. The 90 discs from insolated leaves showed a total of 1,486 nymphs as against a total of 351 nymphs on 90 discs from shaded leaves. The mean difference of 113.5 between the 10 pairs of treatment totals was highly significant at P=0.001.

These tests established that increase in thrips infestations on cacao brought about by light was accompanied by an increase in the attractiveness to the pest of the host plant due to the same factor.

Discussion and Conclusions

The field observations described above have shown that infestations of cacao thrips are increased by lack of shade and that this increase

Table V

Locality.	Date of Test.	No. of Test.	Insolated Leaves Totals for 9 Discs.	Shaded Leaves Totals for 9 Discs.
Maracas Valley ...	18 to 20 Dec., 1941 ...	1	151	30
		2	208	6
North Manzanilla ...	22 to 24 Dec., 1941 ...	3	153	13
		4	136	43
Diego Martin Valley ...	6 to 8 Jan., 1942 ...	5	127	25
		6	137	22
San Rafael	8 to 10 Jan., 1942 ...	7	67	130
		8	140	40
Brasso	20 to 22 Jan., 1942 ...	9	208	14
		10	159	28
	Totals	...	1,486	351
	Means	...	148.6	35.1

is due to accelerated reproduction of the pest. The greenhouse experiments have demonstrated that the light factor is responsible for larger thrips populations in the absence of shade and that this factor shortens the developmental period of the insect. The method of action of light is in part explained by the results of food preference tests which show that cacao leaves become increasingly attractive to thrips nymphs with increase in the amount of light falling on them. Both Davidson (1925) and de Fluiter (1939) have shown that the growth of infestations of sap-sucking insects is accelerated by the action of light on the host plant and it is clear that the thrips-cacao complex is similarly affected. Light indirectly favours thrips incidence by modifying the cacao in some way as yet not understood.

It is probable that in addition to increasing the attractiveness of the leaves light also accelerates thrips reproduction by raising the temperature of the environment. Kirkpatrick (1935) has shown that the temperature of coffee leaves exposed to full sunlight may rise 20°C above that of the surrounding air while that of shaded leaves is rarely more than 2°C above that of the air. Thrips on insolated cacao leaves may be presumed to be at a higher temperature than on leaves under shade, and this difference may affect the degree of infestation.

Field observations yielded no evidence in support of Reyne's theory of positively phototactic migration of thrips adults as a cause of thrips pockets. The results of the second greenhouse experiment show that such a migration is unlikely in the field. This is remarkable in the view of strong positive response to light of adult thrips under laboratory conditions. Franz (1913) observed that when organisms were removed from their natural surroundings and placed in a strange environment they responded positively to light in their efforts to escape. This was not true phototaxis but was an escaping reaction which disappeared when the organism was returned to its natural habitat. Since all Reyne's phototactic experiments were carried out under conditions foreign to the thrips, their behaviour in such an environment must be interpreted in terms of their desire to escape from it. It has yet to be shown that cacao thrips in their natural environment are positively attracted by light and any theory based on this hypothesis must be accepted with reserve.

Acknowledgments

This work was carried out under the supervision of Dr. E. McC. Callan, to whom and to Professor A. M. Adamson I am deeply grateful for advice and criticism. My thanks are due to Professor E. E. Cheesman for the facilities afforded by his department, to Mr. E. R. Leonard for advice and help in obtaining ecological data, and to Dr. E. C. Humphries and Mr. F. W. Cope for advice on the physiology of cacao. I am further indebted to Dr. Humphries for making leaf analyses. I have finally to thank the owners and managers of the various estates for help given in making field observations.

Summary

Field observations were made at fifty stations in five localities in Trinidad, B.W.I. Comparative counts of the number of thrips per leaf on a shaded and an insolated site at each station showed that thrips infestations were significantly heavier on insolated than on shaded cacao, 5,000 leaves on 277 trees on insolated sites having 10,951 thrips while 5,000 leaves on 278 trees under shade had 1,519 thrips. The population of immature to adult thrips was significantly higher under insolated conditions.

Greenhouse experiments, made with thrips infestations on clonal cacao under controlled shade conditions, showed that increase in light falling on cacao increased the incidence of thrips by shortening their developmental period. Positively phototactic migration of adult thrips did not occur.

Food preference tests made in the laboratory with discs cut from leaves from propagator, greenhouse and field cacao showed that leaves growing in more intense light were significantly more attractive to thrips nymphs of the first and second stages.

Light, by modifying the cacao in some way as yet not understood, favours the incidence of thrips by accelerating reproduction. No evidence was found in support of Reyne's theory of positively phototactic migration of adult thrips as a deciding factor in their distribution.

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* Read in review only.

PROGRESS IN SOIL PHYSICS *

[*The following is a review by Dr. T. J. Marshall of the Division of Soils, Council for Scientific and Industrial Research, Adelaide, South Australia of a recent textbook on "Soil Physics"† by Dr. L. D. Baver, Head of the Department of Agronomy of the North Carolina State College, U.S.A.*—EDITOR.]

A great deal has been accomplished in soil physics since the publication of Keen's *Physical Properties of the Soil* in 1931. For this reason, the appearance of several books dealing with advances in this and related fields is very welcome. Of particular interest is L. D. Baver's *Soil Physics*, in which a review is given of the most important developments. A good introduction is provided to the principles of water movement in soils, the physical composition of soils and soil colloids, and the theory of mechanical analysis. The material is logically and clearly presented, along the lines of the author's university lectures, with sufficient treatment of fundamentals to provide a coherence to the whole. This book should be of value to students and research workers alike.

So many aspects of soil physics have a bearing on some relation between soil and water that advances made in the study of the movement of water and its retention in soils have been important to the whole field. Progress has been made possible by the use of the capillary potential theory introduced many years ago by Buckingham. This deals with the energy changes involved when water is added to, or removed from, the soil. Practical applications were limited until suitable methods for measuring the potential had been developed. Since these became available recently, marked advances have been made.

The development of this theory and its bearing on water movement, water retention, availability of water to plants and the specification of soil structure are discussed fully in Baver's book. One simple application will provide an example of its usefulness. The permanent wilting of plants occurs at a higher water content in a clay than in a sandy soil. However, it is shown experimentally that wilting occurs at about the same capillary potential in all soils. In other words, the energy level of the soil water gives a direct measure of the availability of the water to plants.

The capillary potential theory has also made possible the development of new methods for investigating soil structure. Baver has himself made contributions to the measurement of pore size and this, together with his familiarity with

* Reprinted from *Journal of the Australian Institute of Agricultural Science*, Vol. 8, No. 1.

† Soil Physics, by L. D. Baver. (*Pp. xi & 370 with 4 plates, 70 figures and 54 tables. John Wiley & Sons, New York*, 1940. *Price 4 dollars.*)

Russian work, has resulted in an excellent chapter on structure. He points out that in many soils the structural arrangement of the particles is as important as the composition given by complete dispersion in a mechanical analysis. The degree of aggregation and the stability of the aggregates affect the physical behaviour of the soil profoundly. Degeneration of structure, under cropping rotations which involve frequent cultivation, is a major cause of decline in soil fertility. Structure has been studied by dry-sieving, wet-sieving and sedimentation methods, for all of which arbitrary standardisation is necessary. These methods measure aggregate sizes but, for many purposes, the specification of pore sizes would give a more satisfactory picture. This can be accomplished by employing the principle that the largest pores in a soil are emptied first when a progressively increasing tension is applied to soil water. Provided certain theoretical limitations are recognised, it is possible then to obtain a size distribution of the soil pores.

From a knowledge of pore size and total pore space, it should be possible to obtain a good index of the permeability of a soil to fluids. But, as can be seen from Baver's discussion of Slichter's and Zunker's work, attempts to express permeability as a function of the structure have always stressed either particle diameter or specific surface. A departure from this was introduced recently by Bodman, who employed an "effective radius" of pores obtained by relating Poiseuille's law for flow through capillary tubes and Darcy's law for flow through porous media. A still more direct approach has been made possible by considering the distribution of pore sizes in the medium. Baver provides some useful correlations of permeability with the occurrence of the larger pores, but a critical evaluation has yet to be made of the effectiveness of the different pore sizes in contributing to the permeability of the whole. This should provide a promising line of future investigation.

For the usual permeability determinations, flow is measured under saturated conditions. Recently however, techniques have been developed for measuring flow in soils and soil colloids maintained at any required degree of unsaturation. In such cases the water moving force is given by the sum of the gradients in capillary and gravitational potential. Baver deals at some length with the results of these experiments. They have shown quantitatively that water conductivity or permeability decreases rapidly as the tension and degree of unsaturation increase. This has an important bearing on the management of fallows following summer rains. By the time a soil has drained and evaporated sufficient water to be in a fit condition for cultivation, the rate of water movement by conduction will have greatly decreased. Mulching of the surface at that stage cannot be very effective in restricting water loss.

When there is a shallow water-table, on the other hand, upward movement will often be sufficiently rapid to allow significant conduction of water to the surface. Under these circumstances (which are those of the classical experiments of King), the creation of a dust-mulch can be effective in restricting water loss. There are many other cases more particularly in sub-soils when flow under unsaturated conditions is important. In this connection, Baver quotes freely from Moore, who has demonstrated the very interesting fact that, when soils are unsaturated, movement is more rapid in a clayey soil than it is at a corresponding potential in a sand.

In dealing with soil erosion, Baver has made a commendable selection from the large volume of work now being undertaken in that field. In a descriptive equation, he defines erosion as a function of climate, topography, vegetation and soils. Climate and vegetation are of course of prime importance and are usefully discussed in this section. While angle of slope does not affect run-off greatly it has an important influence on the degree of erosion of a soil. Of the soil properties influencing run-off and erosion, the one most widely studied is that of infiltration or the rate of entry of water into the soil. This is measured by allowing water to enter the soil under a low head, or under the application of artificial rain. The initial water content of the soil is of course an important factor influencing infiltration and, where water is being continuously applied, the rate of entry falls off with time. The results obtained by such measurements have a close bearing on the relation of climatic factors to run-off and erosion. Questions of structure also enter into the picture, particularly when the soil is cultivated and the surface suffers from the direct impact of falling rain drops. Baver discusses fully the significance of stability of structure and degree of aggregation in relation to erosion. He points out that, while good granulation may reduce erosion with light rains, compaction may in some cases be more effective under heavy rains. In general, however, any factors assisting permeability will help also to resist run-off and erosion. The effects of the various soil factors on erosion are usefully summarised at the end of this section in a further descriptive equation.

RAT CONTROL

Further study by the Hawaiian Experiment Station* of poison bait acceptance by field rats confirms confidence in thallium sulphate; but to obtain the best results it was found necessary that the "pre-bait period" of feeding with unpoisoned material as rolled oats should be followed by an abrupt change to the thallium-treated rolled oats. When this was done it was found that the acceptance of the thallium bait was twice that of barium bait. Acceptance in the case of red squill was very poor.—(*International Sugar Journal*, Vol. XLIII, p. 379.)

* *Report of the Committee in Charge of the Experiment Station, Hawaiian* S. P. A., 1940, pp. 92-94.

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Sources of Rubber

There are about 200 uses for rubber in the modern automobile. Consumption of rubber in 1917 in U.S.A. was only about 60,000 tons a year, but in 1941 it was nearly that amount a month. More than 2,000 *Hevea* trees, raised in Miami during the last 17 years, are producing latex that compares favourably with that obtained from the East Indies. Twenty-nine varieties of synthetic rubber have been studied critically. Among the more satisfactory products may be listed Ameripol, Buna-S, Butyl rubber, Chemigum, Hycar, Koroseal, Methyl-rubber, Neoprene, Perbunan, Sovprene, Synthal, Thiokol, and Vistanex. When vats of milkweed are inoculated with certain forms of bacteria and allowed to ferment, a rubber-like product is obtained which is particularly adapted to bullet-proofing gasoline tanks, according to W. A. Sharp, a California inventor. The guayule plant, which has been developed in the arid regions of southwestern U.S.A. by General Tire and Rubber Company, has a rubber content of about 23 per cent. It is considered that selection would increase this figure to about 30 per cent. Under a five-year cycle plan, it is believed that this plant will produce rubber for about 20 cents per pound. A dandelion known as kok-sagnyz, discovered and grown in Russia has merit as a rubber-producing crop that appears to be equal or superior to that of the guayule plant that is being developed in the southwestern states—*(Journ. Chemical Education*, Vol. 19, 1942, p. 152.*)*

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Development of the Coconut and Factors influencing the Copra Content of the Nut

The factors affecting the development of the fruit of the coconut are discussed in articles by P. M. L. Tammes which were published in *Landbouw* (16, 385-95) and *Bergcultures* (14, 1101-7). Drought delays development, reducing the growth of young nuts. The older leaves often die off too early and with them the young trusses. The nuts drop and mature too soon with the result that they are deficient in copra. When it requires more than 500 nuts to provide 100 kg. of dried copra, it is an indication that there has been insufficient moisture.

Little is known of the influence of excessive rainfall and it is not certain whether the occasional bursting of young nuts has any connection with it. As a general rule the only situation in which heavy rainfall is not beneficial is when the trees are growing on swampy soils or on soils deficient in minerals. On such soils the trees do better in the dry season.

Unfavourable soil conditions produce such symptoms as low yields, untimely dying off of older leaves and their flower trusses, shrivelled copra, yellowish leaves and, in the worst cases, thinning of the stem and the death of the tree.

Various fungus diseases and insect pests reduce the copra yield either by killing off the leaves and causing premature nut fall. Also by their attacks they so injure the internal economy of the tree that the young nuts fail to make copra.

With regard to harvesting, for the sake of economy, the intervals between pickings should be as long as possible. The time varies with the country from two months to one month. Nuts picked too soon have less copra, those left too long on the tree may start to germinate.

* * *

Factors affecting the Formation of Soil Crusts

A main factor in crust formation is the presence of fine particles greater than 0.01 mm. in diameter. Crusts are formed on structureless fine-grained soils possessing plasticity when wet. Salts in the soil solution are not important in crust formation. Although they cause a disaggregation of micro-aggregates this has little effect on the final settling of the soil. The greater is the number of fine particles in the soil and the slower the movement of water in the capillaries during evaporation, the more marked is the difference in the moisture of contiguous soil layers, this being the principal cause of cracks appearing on the surface of the soil. The quantity and quality of the humus are important, but in structureless fine-grained soils, crusts are formed regardless of the humus content. —(*Brit. Chem. Phys. Abstrs.*, B. III, p. 313.)

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Effect of Structure of Artificial Rain on Character of the Moistening and on the Agro-physical Properties of the Soil

Intensification of the spray when using sprinkling irrigation destroys soil structure, decreases depth of water penetration, and increases run-off. Increasing the size of drops in the spray also increases the destructive effect on soil structure. The optimum intensity of spray is 0.2 mm/min., at which rate no destruction of soil structure takes place, but small aggregates are formed and a maximum depth of penetration results. The optimum diameter for the drops in the spray was 2-3 mm.—(*Brit. Chem. Phys. Abstrs.*, B. III, p. 310.)

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Effect of Manure and Clover in improving Soil Structure and Physico-chemical Properties of Water-stable Aggregates

Although manure is an essential factor for the improvement of soil structure, the simultaneous use of both manure and clover was even more effective in increasing the water-stability of aggregates. The larger aggregates contained more organic matter than the small ones. A seasonal variation was noted in the number of water-stable aggregates, the lowest amount being present in the spring. Under air-dry conditions the index of structure was 1.5-2 times that under field conditions.—(*Brit. Chem. Phys. Abstrs.*, B. III, p. 318.)